9.3 Blood pressure measurements in Study II

9.3.1 Introduction

As Study I suggested an association between populations' health and the Transmitter's EMF,our main concern was the reliability of self-reported health or illness. In order to measure the reliability, answers to questions in Study I had to be compared with a 'gold standard' diagnosis. We considered as a 'gold standard' diagnosis either a measurement procedure that could be easily performed by ourselves or by a skilled physician. Since changed blood pressure seemed to occur with statistically different frequency between Zones A, B and C, and blood pressure measurements are easy to perform under field conditions, we chose this method for a validation study. This also gave us an opportunity to study wether under-, respectively over-reporting of hypertension was independent of the exposure classification. Thirty-nine persons had reported a diagnosis of 'arterial hypertension' and 58 had answered that their blood pressure was 'too high'. In order to obtain a reasonable sample, we decided to verify the answer to the inquiry about blood pressure rather than to verify the diagnosis of 'hypertension'. Since only hypertension is considered to be of clinical importance, we recorded the answers to the question about the blood pressure to the categories 'not hypertensive', which included the answers 'normal', 'too low' and 'I don't know', and 'my blood pressure is too high'.

9.3.2 Method

All 58 persons who had answered the question about their blood pressure with 'too high' were contacted. A systematic random sample of 58 persons who had answered the question in the sense of not having an increased blood pressure were selected from the health interview survey regardless of Zones, age and sex, and contacted.

On 3 occasions with a minimum time interval of 3 days, 3 physicians from our team (E. Altpeter, R. Blattmann, Th. Krebs) carried out blood pressure measurements. Prior to each of these, the participants had to rest on a bed at least 5 minutes . At the first investigation, body height and weight were measured, the participants' medication was recorded, and in the cases of repeated hypertensive blood pressure values the participants were asked for written informed consent to allow us to contact their general practitioner or internist.

Blood pressure was considered as hypertensive, if at least 2 out of 3 measurements were $\geq$ 160 systolic or $\geq$ 95 diastolic, or when a patient taking medication for lowering blood pressure suffered from hypertension diagnosed by her or his physician.

9.3.3 Statistical Analysis

Consider the following 2×2 table

Disease\Test	positive	negative	Total
present	a	b	a+b
absent	c	d	c+d
Total	a+c	b+d	n=a+b+c+d

then sensitivity is defined by

$$\frac{a}{a+b},$$

and specificity by

$$\frac{d}{c+d}.$$

In our study we considered the inquiry about blood pressure to be the test, and the confirmation of blood pressure values obtained by measuring or from the participants' physicians to be the 'gold standard' for classification as 'Disease' present or absent.

Another method to analyze the 2×2 way table is to consider the two methods of investigating hypertension as two independent rates. On this assumption the interrater agreement κ can be estimated. κ is a chance adjusted measure of agreement. After dividing the cells in the 2×2 table by $n = a + b + c + d$ we obtain the observed proportions, and the table can be presented as follows:

Disease\Test	positive	negative	Total
present	a	b	p_1
absent	c	d	q_1
Total	p_2	q_2	1

The expected value for a is calculated by $a_e = p_1 p_2$. From this it can be concluded that

$$\widehat{\kappa} = \frac{2(ad - bc)}{p_1 q_2 + p_2 q_1}$$

is a chance adjusted measure of interrater agreement and approximated 95% C.I. can be constructed [Fleiss (1981)].

9.3.4 Results

Forty-five persons (45/58, 78%) who had and 50 persons (50/58, 86%) who had not answer that their blood pressure was 'too high' participated. After the first consultation it turned out that 9 persons (9/45) did not suffer from hypertension but that on occasions such as donating blood or a visit at a pharmacy an increased blood pressure level had been observed. In 1 out of these 9 cases increased blood pressure levels had been recorded during pregnancy. Remaining 36 persons who had indicated that their blood pressure was too high' had increased blood pressure levels at two out of three visits or underwent antihypertensive treatment. These were asked for consent to contact their physicians. Nine physicians were contacted and all responded to our inquiry: the diagnosis "hypertension" was confirmed in all 36 persons. In one case the diagnosis was established by repeated values between 145/95 and 160/95. This case was thus considered as not hypertensive although the diagnosis was established by the physician. As a result we obtained the following 2×2 table

Hypertension\Question	'too high'	not 'too high'	Total
present	35	5	40
absent	10	45	55
Total	45	50	95

We obtained a sensitivity of 88% and a specificity of 82%. The interrater agreement is calculated by

$$\kappa = \frac{2 \cdot \left(\frac{35}{95} \cdot \frac{45}{95} - \frac{5}{95} \cdot \frac{45}{95}\right)}{\frac{40}{95} \cdot \frac{50}{95} + \frac{45}{95} \cdot \frac{55}{95}} = 0.603,$$

which is fairly high.

In Study I we had observed 15 respectively 24 persons in Zone A respectively in Zones B and C who declared that they suffered from diagnosed hypertension . Three $(15 \cdot 10/45)$ and 5 $(24 \cdot 10/45)$ participants thus had to be considered as not being hypertensive, and 9 $(90 \cdot 5/50)$ and 27 $(275 \cdot 5/50)$ respectively as suffering from hypertension without being aware of it. This led to the following table

Disease\Exposure	present	absent	Total
present	21	46	67
absent	84	253	337
Total	105	299	404

From this table we obtained an odd's ratio of 1.4. On the assumption that our correction factors (10/45 and 5/50) are quite precise, 95% C.I. for the odd's ratio can be estimated $0.75 < OR < 2.52$. This allows us to conclude that there is no obvious association between exposure and increased blood pressure.

9.4 Discussion and Conclusion

The purpose of the Shortwave Transmitter Schwarzenburg Study was to examine whether the Transmitter's electromagnetic field could be associated with ill health. As the health interview survey in 1992 suggested that there might be an effect on blood pressure, we were interested in establishing whether this finding could be confirmed by measurements and information provided by the participants' physicians. Since low blood pressure is not associated with serious diseases we focused on hypertension; this in particular because we had found a slight, but insignificant increase of the odd's ratio.

This finding required further investigation; in particular the influence of under- or overreporting on the odd's ratio was not clear. Our results, however, show that no association between hypertension and EMF-exposure in the shortwave range could be demonstrated.

It is of interest that self-reported blood pressure levels was a reliable indicator, with a sensitivity of 88% and a specificity of 82%. The chance-adjusted agreement between self-reported blood pressure and a diagnosis of hypertension confirmed by measurements and by the participants' physicians was unexpectedly high $\kappa = 0.6$. Ten per cent of the participants did not know that their blood pressure levels were increased, and 20% of the participants had reported increased blood pressure levels on the bases of occasional observations.

Conclusion

No association between hypertension and EMF-exposure in the shortwave range could be established.

Bibliography

[1] Fleiss JL (1981), Statistical Methods for Rates and Proportions, John Wiley & Sons, New York.

the Transmitter's electromagnetic field seems unlikely, it cannot be excluded. A more sophisticated study including psychological testing is not possible due to the small number of schoolchildren in this small rural population of limit size.
Keywords: ae (adverse effects), radiowaves, schoolchildren

10.1 Introduction

The objective of the Shortwave Transmitter Schwarzenburg Study was to find out if the complaints of the population living in its surroundings were justified. In a petition of 1989 the petitioners claimed ill health of adults and children. They especially pointed out that the children showed a strange behaviour. Whereas Study I had focused on adults, in Study II we wanted to establish whether there was some evidence that the children living in the exposed school district differ from unexposed children.

10.1.1 Literature review on children and EMF

There is no evidence that electromagnetic fields in the shortwave-frequency range do any harm to children. As for the low-frequency range e.g. 50 Hz, there is an extensive debate going on about its potential to either induce or promote leukemia and brain tumors like neuroblastoma. The studies indicating a significant effect on the rates of leukemia are not widely accepted (see Bibliography).

10.1.2 Options of studying performance of schoolchildren

When studying performance of schoolchildren, we had to realize at first whether we were interested in a chronic effect or in an acute effect, as this determined the choice of the test as well as the design of the study. Furthermore, we had to establish the size of the potential study population.

In order to obtain interpretable results we had to control for

1. the children's age
2. the children's housing
3. the parents' attitude to and their influence on childrens' upbringing
4. the teacher's opinion on the Transmitter and its influence on schoolchildren

Not only the design determined the choice of the method but also the size of the potential study population. Since age is of critical importance at primary school level we decided to focus on children of the age of about eleven which corresponds to the fourth class level. In a first step we decided to carry out an exploratory retrospective analysis of the promotion rates from primary to secondary school. This allowed us to establish whether the population would be large enough to allow for a more detailed study, as well as to answer the question whether there would be some evidence of difference in promotion rates between exposed and unexposed areas.

10.1.3 School Organization at Schwarzenburg

The school system in Switzerland is based on a federal principle, e.g. within a given legal framework every municipality is allowed to organize its school at its convenience. In the Canton of Bern there are basically three school levels: primary, secondary and high school. The primary school truck has nine years and allows for the lowest level of completion of compulsory education. Until 1994, the more talented children could shift into the secondary school track of 5 years duration after completing the first four years of primary school. After secondary school the students could promote to high school. After 1994, promotion to secondary school was postponed to the end of the sixth grade, but this change has no relevance to this study, which was conducted in 1993.

10.2 Methodology

The 7 headmasters of the primary schools of the municipality of Wahlern (Schwarzenburg) were contacted. Unfortunately only 2 answered positively to our letter: one of the exposed school at Mamishaus and one of the unexposed school at Moos. They were asked to provide us with the total numbers of children in the school classes at level four respectively five and the number of promoted schoolchildren going back as far as available.

Given the geographical situation of the school districts, all children at the school of Mamishaus had to be considered as exposed (see the maps), and all children at the school of Moos could be considered as unexposed. The earliest numbers available at Mamishaus dated from 1954, after this school had been opened in the early fifties.

In order to obtain an overall estimate of the promotion rate, every year was considered to be a cluster and a Mantel-Haenszel weighted Odd's ratio and χ^2 was estimated by EPI-INFO. The rates were displayed graphically and smoothened with a robust algorithm ('supsmu') by Splus Vers. 3.2 under Windows 3.1 on a PC.

10.3 Results

The data are summarized in Table 10.1. Because the numbers are small the promotion rates are not given in percent. The small numbers also indicate that a study at the forth class level would be of small power. Therefore, no further evaluations were planned.

	Promotion rates			Promotion rates	
Year	Exposed	Unexposed	Year	Exposed	Unexposed
1954	0/18	5/21	1974	3/17	1/8
1955	0/19	2/9	1975	4/10	6/15
1956	0/17	3/15	1976	3/18	0/7
1957	0/15	2/15	1977	2/17	4/13
1958	1/20	1/14	1978	3/13	2/11
1959	0/17	2/12	1979	2/11	2/9
1960	0/18	3/13	1980	3/9	4/12
1961	3/16	6/22	1981	1/10	5/6
1962	7/17	2/9	1982	1/2	4/9
1963	3/11	2/9	1983	1/6	10/12
1964	4/15	5/14	1984	1/5	4/5
1965	4/13	1/13	1985	4/12	3/7
1966	5/13	3/14	1986	2/10	2/8
1967	0/12	2/14	1987	1/8	3/7
1968	1/13	1/10	1988	8/14	1/7
1969	4/19	4/9	1989	4/9	3/9
1970	0/15	2/7	1990	3/5	0/4
1971	2/11	5/10	1991	3/11	1/3
1972	4/12	2/9	1992	5/12	6/8
1973	3/14	1/9	1993	4/9	2/5

Table 10.1: Promotion rates from primary to secondary school level

Children at Mamishaus school have a significantly smaller chance to promote to secondary school level than children at Moos (OR 0.43<0.63<0.85; Mantel-Haenszel weighted $\chi^2 = 8.04$, $p < 0.005$). The differences occurred mainly at the end of the fifties, sixties and during the beginning of the eighties. The time trend is difficult to explain only by the raise of exposure. As the school districts have a similar socioeconomic structure and both are in a rural area such differences do not explain the scholastic outcome. It is, however, known that the regulations for promotion changed in the course of the past decades. From 1953 to 1960 children could promote at the end of the fifth grade. 1960/61 they could either promote at the end of the fourth or fifth grade. From 1962 promotion was possible after the fourth class level. During this period the promotion regulations changed several times, and it is actually difficult to trace back when and how they really changed. It is, however, known that from the early sixties to the mid-eighties promotion was only possible upon the recommendation of the teacher and dependent on the result of an examination. Thus the differences between the two promotion rates might result from teachers' different requirements for recommending promotion. In recent times the promotion rates have evolved almost equally.

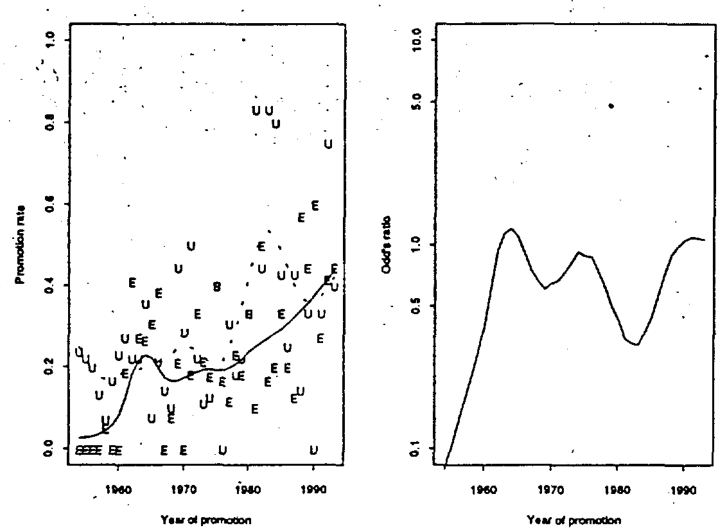


Figure 10.1: *Promotion rates from primary to secondary school level. The left panel shows the absolute promotion rates. The 'E' points indicate the promotion rates for the exposed children, the 'U' points for the unexposed children. The full line smoothens the rates of the exposed and the dashed line of the unexposed promotion rates. The right panel shows the odd's ratio obtained after smoothening (see text).*

10.4 Discussion and Conclusion

To our knowledge there are no studies available which would have tested the hypothesis that electromagnetic fields of the range of 3-30 MHz could cause any harm to children. A study of rare, severe diseases such as cancer was considered impossible in the present situation given the small numbers of exposed children. We therefore based our hypotheses on the complaints voiced in the neighbourhood of the Transmitter and tried to establish whether indications for harm in terms of psychological malfunctioning could be found.

The data suggest a decreased promotion rate of exposed schoolchildren in comparison with the unexposed ones. Therefore an adverse effect cannot be excluded. It was, however, impossible to control for important confounders such as teachers' requirements for proposing the promotion or the view of the parents whether secondary education is of benefit to their children or not. The cyclical behavior of the relative promotion rates is strongly suspicious in relation to such effects. It has, however, to be stressed that this difference can be explained neither by the socioeconomic status in the school districts of Mamishaus and Moos nor by the difference of the educational systems at the two sites, as these are very similar.

A selection bias concerning the control school cannot be excluded. Of five contacted schools outside the exposed zone only one headmaster agreed to participate, and it could perhaps be related to a particularly good performance record.

Nevertheless, since promotion is an important social step, our finding of a difference in promotion rates would justify further investigations such as extensive psychological testing. But the total numbers of children do not allow to properly design a study of a sufficient power in the population of schoolchildren exposed to the Transmitter of Schwarzenburg (see Table 10.1 on page 129).

Conclusion

A potential effect on school promotion rates due to the Transmitter's electromagnetic fields seems unlikely, but cannot be entirely excluded. More sophisticated studies would have to be conducted elsewhere, as due to small numbers of children such studies would not be possible in our study population..

Bibliography

[1] Ahlbom A, Feychting M, Koskenvuo M, Olsen JH, Pukkala E, Schulgen G, Verkasalo P (1993): Electromagnetic fields and childhood cancer (letter). Lancet 342:1295-1296.

[2] Bates MN (1991): Extremely low frequency electromagnetic fields and cancer: the epidemiologic evidence. Environ Health Perspect 95:147-156.

[3] Bracken MB (1992): Re: "Exposure to residential electric and magnetic fields and risk of childhood leukemia" (letter; comment). Am J Epidemiol 135:1069-1070.

[4] Bracken TD, Kheifets LI, Sussman SS (1993): Exposure assessment for power frequency electric and magnetic fields (EMF) and its application to epidemiologic studies. J Expo Anal Environ Epidemiol 3:1-22.

[5] Brouwer FP (1995): Re: "Case-control study of childhood cancer and exposure to 60-HZ magnetic fields" (letter). Am J Epidemiol 141:375-378.

[6] Cossarizza A, Monti D, Bersani F, Scarfi MR, Zanotti M, Cadossi R, Franceschi C (1991): Exposure to low-frequency pulsed electromagnetic fields increases mitogen-induced lymphocyte proliferation in Down's syndrome. Aging 3:241-246.

[7] Cox RA (1990): Health effects of electromagnetic fields (see comments). J R Soc Med 83:63-64.

[8] Delpizzo V (1991): Exposure to high tension power lines and childhood leukaemia (letter; comment). Med J Aust 155:854

[9] Draper G (1993): Electromagnetic fields and childhood cancer (editorial; comment). BMJ 307:884-885.

[10] Feychting M, Ahlbom A (1993): Magnetic fields and cancer in children residing near Swedish high- voltage power lines. Am J Epidemiol 138:467-481.

[11] Florig HK (1992): Containing the costs of the EMF problem (see comments). Science 257:468-469.

[12] Foster KR (1992): Health effects of low-level electromagnetic fields: phantom or not- so-phantom risk? Health Phys 62:429-435.

[13] Goldberg RB, Creasey WA (1991): A review of cancer induction by extremely low frequency electromagnetic fields. Is there a plausible mechanism? Med Hypotheses 35:265-274.

[14] Hatch M (1992): The epidemiology of electric and magnetic field exposures in the power frequency range and reproductive outcomes. Paediatr Perinat Epidemiol 6:198-214.

[15] Hendee WR, Boteler JC (1994): The question of health effects from exposure to electromagnetic fields. Health Phys 66:127-136.

[16] Jackson JD (1992): Are the stray 60-Hz electromagnetic fields associated with the distribution and use of electric power a significant cause of cancer? Proc Natl Acad Sci U S A 89:3508-3510.

[17] Järmann H.(1994), personal communications.

[18] Jauchem J (1993): Alleged health effects of electric or magnetic fields: additional misconceptions in the literature. J Microw Power Electromagn Energy 28:140-155.

[19] Jauchem JR (1990): Electromagnetic fields and cancer (letter; comment). Science 250:739

[20] Jones TL, Shih CH, Thurston DH, Ware BJ, Cole P (1993): Selection bias from differential residential mobility as an explanation for associations of wire codes with childhood cancer. J Clin Epidemiol 46:545-548.

[21] Kavet R (1991): An alternate hypothesis for the association between electrical wiring configurations and cancer. Epidemiology 2:224-229.

[22] Knave B (1994): Electric and magnetic fields and health outcomes–an overview. Scand J Work Environ Health 20 Spec No:78-89.

[23] Krause M, Westneat D (1991): Possible link to cancer fuels debate regarding effects of magnetic fields. Occup Health Saf 60:28-30.

[24] Kraut A, Tate R, Tran N (1994): Residential electric consumption and childhood cancer in Canada (1971-1986). Arch Environ Health 49:156-159.

[25] Lin RS, Lee WC (1994): Risk of childhood leukemia in areas passed by high power lines. Rev Environ Health 10:97-103.

[26] London SJ, Thomas DC, Bowman JD, Sobel E, Cheng TC, Peters JM (1991): Exposure to residential electric and magnetic fields and risk of childhood leukemia (published erratum appears in Am J Epidemiol 1993 Feb 1; 137(3):381) (see comments). Am J Epidemiol 134:923-937.

[27] Macklis RM (1993): Magnetic healing, quackery, and the debate about the health effects of electromagnetic fields. Ann Intern Med 118:376-383.

[28] Mundt KA (1992): Re: "Exposure to residential electric and magnetic fields and risk of childhood leukemia" and "case-control study of childhood cancer and exposure to 60-Hz magnetic fields" (letter; comment). Am J Epidemiol 135:1070-1075.

[29] Olsen JH, Nielsen A, Schulgen G (1993): Residence near high voltage facilities and risk of cancer in children (see comments). BMJ 307:891-895.

[30] Omenn GS (1991): Policy aspects of epidemiologic studies of possible health effects of electric and magnetic fields from power lines. Public Health Rev 19:35-38.

[31] Petridou E, Hsieh CC, Skalkidis Y, Toupadaki N, Athanassopoulos Y (1993): Suggestion of concomitant changes of electric power consumption and childhood leukemia in Greece. Scand J Soc Med 21:281-285.

[32] Polakoff PL (1993): Scientists continue quest for the link between electromagnetic fields, cancer. Occup Health Saf 62:32-34.

[33] Reizenstein P (1993): Leukemia and electromagnetic fields (editorial) (published erratum appears in Leuk Res 1993 Apr; 17(4):395). Leuk Res 17:197-198.

[34] Ross R (1988): Do power line-generated electromagnetic fields have any association with certain disorders? (news). JAMA 259:1131-1133.

[35] Sahl JD (1994): Viral contacts confound studies of childhood leukemia and high-voltage transmission lines. Cancer Causes Control 5:279-283.

[36] Savitz DA (1993): Epidemiologic studies of electric and magnetic fields and cancer: strategies for extending knowledge. Environ Health Perspect 101 Suppl 4:83-91.

[37] Savitz DA, Kaune WT (1993): Childhood cancer in relation to a modified residential wire code. Environ Health Perspect 101:76-80.

[38] Savitz DA (1993): Overview of epidemiologic research on electric and magnetic fields and cancer. Am Ind Hyg Assoc J 54:197-204.

[39] Savitz DA, Feingold L (1989): Association of childhood cancer with residential traffic density. Scand J Work Environ Health 15:360-363.

[40] Savitz DA, Wachtel H, Barnes FA, John EM, Tvrdik JG (1988): Case-control study of childhood cancer and exposure to 60-Hz magnetic fields (see comments). Am J Epidemiol 128:21-38.

[41] Schulgen G, Lausen B, Olsen JH, Schumacher M (1994): Outcome-oriented cutpoints in analysis of quantitative exposures. Am J Epidemiol 140:172-184.

[42] Sheikh K (1986): Exposure to electromagnetic fields and the risk of leukemia. Arch Environ Health 41:56-63.

[43] Siemiatycki J (1993): Problems and priorities in epidemiologic research on human health effects related to wiring code and electric and magnetic fields. Environ Health Perspect 101 Suppl 4:135-141.

[44] Stevens RG (1994): Re: "Magnetic fields and cancer in children residing near Swedish high-voltage power lines (letter). Am J Epidemiol 140:75

[45] Tar Ching AW (1988): Living under pylons (editorial). BMJ 297:804-805.

[46] Taubes G (1993): EMF-cancer links: yes, no, and maybe (news). Science 262:649

[47] Taylor H (1991): EMF primer. NEHW Health Watch 11:5-6.

[48] Theriault G (1992): Electromagnetic fields and cancer risks. Rev Epidemiol Sante Publique 40 Suppl 1:S55-62.

[49] Tomenius L (1986): 50-Hz electromagnetic environment and the incidence of childhood tumors in Stockholm County. Bioelectromagnetics 7:191-207.

[50] Trainor L (1993): Electromagnetic effects on people. Folia Med Cracov 34:173-178.

[51] Verkasalo PK, Pukkala E, Hongisto MY, Valjus JE, Jarvinen PJ, Heikkila KV, Koskenvuo M (1993): Risk of cancer in Finnish children living close to power lines (see comments). BMJ 307:895-899.

[52] Washburn EP, Orza MJ, Berlin JA, Nicholson WJ, Todd AC, Frumkin H, Chalmers TC (1994): Residential proximity to electricity transmission and distribution equipment and risk of childhood leukemia, childhood lymphoma, and childhood nervous system tumors: systematic review, evaluation, and meta-analysis. Cancer Causes Control 5:299-309.

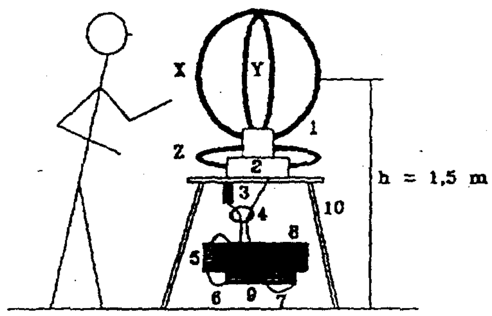
[53] Wilson R, Shlyakhter A (1995): Re: "Magnetic fields and cancer in children residing near Swedish high-voltage power lines" (letter). Am J Epidemiol 141:378-379.

[54] Wyss F. (1994), personal communications.

Appendix A

Measuring Systems

A.1 Loop antenna system



1:	loop antenna Rhode & Schwarz HFH-Z2
2:	mechanical construction enabling to turn the loop antenna into the 3 axes x, y, and z
3:	attenuator 20dB
4:	ferrite
5:	attenuator 10dB
6:	signal cable, around 1 meter
7:	supply cable, around 1 meter
8:	measuring receiver chase 4301
9:	power supply
10:	wooden support

Specification of the system		
H-field range	0.2-26.6	mA/m
frequency range	100-30'000	kHz
antenna accuracy	-1/+1	dB
receiver accuracy	-1.5/+1.5	dB
accuracy under modulation	-1/+1	dB
impedance mismatch error	-0/+1	dB

A.2 Isotopic sensor system

In order to reliably measure the extremely non-uniform EMF of the short-wave transmitter inside buildings, a fully isotropic probe, capable of measuring independently and simultaneously the E- and H-field had to be used. Furthermore due to the relatively low field levels which had to be measured, the dynamic range of the existing probe EH 30 LW had to be modified, resulting in the special version of type EH 30 KW (EMC-Baden Ltd, Dättwil, Switzerland).

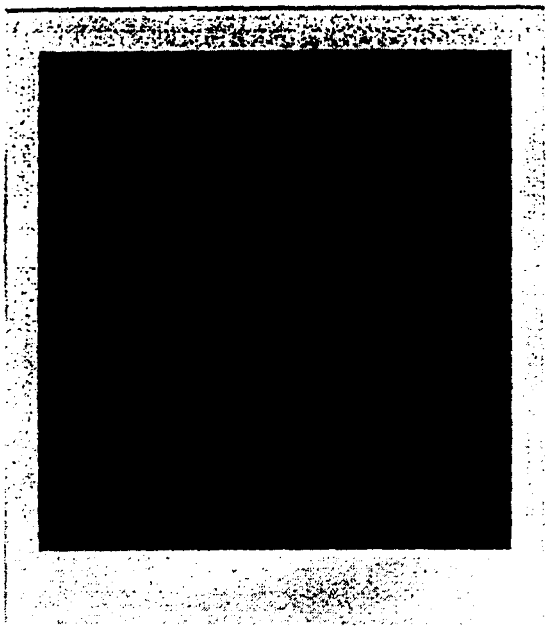


Figure A.1: Probe type EH 30 KW, EMC Baden Ltd., Dättwill, Switzerland

A.2.1 Basic features of the probe

- isotropic antenna system

- simultaneous measurement of 6 field components (3 for the electric, 3 for the magnetic field)
- broadband measurements
- calculation of the Poynting vector
- calculation of the equivalent field strength.

A.2.2 Specifications of the probe EH 30 KW

E-field range	0.1-60	V/m
H-field range	0.5-75	mA/m
frequency range	2-30	MHz
AM-frequency range	50-7500	Hz
linearity error	±0.25	dB
flatness of frequency response	±1.00	dB
isotropy in uniform fields	±1.00	dB
calibration absolute uncertainty	±1.00	dB
acquisition time	30-50	dB

The calibration was performed by the National Institute of Standards and Technology, Boulder, CO, USA (Calibration report No. 812728, January 1993).

Appendix B

Definition of the equivalent field strength

A sinusoidal electric field $\overrightarrow{E}(t)$ at a given point in space can be described by

$$\overrightarrow{E}(t) = \overrightarrow{x}\cdot E_x\cdot\cos(\omega t+\Phi_x)+\overrightarrow{y}\cdot E_y\cdot\cos(\omega t+\Phi_y)+\overrightarrow{z}\cdot E_z\cdot\cos(\omega t+\Phi_z), \quad \text{(B.1)}$$

where x, y, z mean orthogonal axes of the coordination system, t means the time, E_x, E_y, E_z the amplitudes (peak values), Φ_x, Φ_y, Φ_z the phase angles, $\overrightarrow{x}$, $\overrightarrow{y}$, $\overrightarrow{z}$ the unit vectors along the coordinate axes and $\omega = 2\pi f$ the angular frequency of the field. The field magnitude $|E(x, y, z, t)|$ is given by

$$|E(t)| = \sqrt{(E_x\cos(\omega t+\Phi_x))^2 + (E_y\cos(\omega t+\Phi_y))^2 + (E_z\cos(\omega t+\Phi_z))^2}. \quad \text{(B.2)}$$

The effective field strength E_{eff} is a scalar quantity and is given by

$$E_{eff} = \sqrt{\frac{1}{T}\int_0^T |E(t)|^2\,dt} = \sqrt{\frac{1}{2}(E_x^2+E_y^2+E_z^2)}, \quad \text{(B.3)}$$

where $T = \frac{1}{f}$ denotes the time period.

Instead of the peak values E_x, E_y, E_z very often the root-mean-square (rms) values $E_{x,rms}$, $E_{y,rms}$, $E_{z,rms}$ are used, which are smaller by a factor of $\sqrt{2}$. Equation B.3 may thus be written

$$E_{eff} = \sqrt{E_{x,rms}^2 + E_{y,rms}^2 + E_{z,rms}^2}. \quad \text{(B.4)}$$

In the standards such as IRPA "root-sum-square" fields E_{rss} and "equivalent" fields E_{eq} are defined according to the right hand side of Equation B.4. Therefore, E_{eq}, E_{rss} and E_{eff} are equal to each other

$$E_{eq} = E_{rss} = E_{eff} = \sqrt{E_{x,rms}^2 + E_{y,rms}^2 + E_{z,rms}^2}. \quad \text{(B.5)}$$

Obviously, the mutual phase shifts between the field components (see Equation B.1) which often occur in near-field regions, do not have any influence upon E_{eq}. The E field vector rotates as a function of time, the tip of the vector describing an ellipse called the polarization ellipse. If the field components are given as rms values ($E_{x,rms}$ etc.), the $|E|_{\max}$ field is also rms. $|E|_{\max}$ corresponds to the RMS value which would be measured by a single axis instrument whose sensor is aligned such as to obtain maximum reading (i.e. parallel to the major axis of the polarization ellipse). It can be shown easily that the above defined E_{eff} and $|E|_{\max}$ (rms) are equal to each other only in the case of equal phase angles (linear polarization), in general (elliptical polarizations) $|E|_{\max}$, is lower than E_{eq}, usually by a factor in the range 1.0 – 1.41 (see Equation B.6).

$$|E|_{\max} = \begin{cases} E_{eq}, \text{ if } \Phi_x = \Phi_y = \Phi_z \\ \frac{E_{eq}}{1.0...1.41} = (0.71...1.0) \cdot E_{eq}, \text{ (elliptical polarisation)} \end{cases} \tag{B.6}$$

$|E|_{\max}$ is therefore either equal to or less than E_{eq}, the ratio $|E|_{\max}/E_{eq}$ lies within the limits 0.71 and 1.0. The lower limit of 0.71 corresponds to $-3\ dB$, the upper limit of 1.0 to $0\ dB$. $|E|_{\max}$ however neglects any field components perpendicular to the major axis of the polarization ellipse while in E_{eq} all field contributions are included with equal weight. Similar equations also apply to the magnetic field $\overrightarrow{H}(x, y, z, t)$.

Source: Manufacturer of the EH30KW sensor, EMC Baden Ltd, c/o ABB Research Center, 5405 Dätwill.

Appendix C

Uncertainty of exposure assessment in the Study II

In the Table C.1 five types of uncertainties are distinguished: The uncertainty of the measurement itself; the uncertainty due to unknown polarization of the field ; temporal variations of the field between the time of measurement and the time of the medical investigation; spatial variation of the field between the point of measurement and the position of the person; dosimetric uncertainties due to unknown site of interaction of the field on or in the human body.

The measurement uncertainties are reliably known from the measurement system specification. The uncertainty due to unknown polarizations of the field is derived from theoretical arguments (Appendix B)

Temporal variations are estimated. Spatial variations are taken from a case study using numerical simulation of the field distribution in a typical bedroom.

Dosimetric uncertainties are taken from the same numerical simulation. The range indicated encompasses various situations which have been modelled. The parameters varied are the polarization of the field with respect to the axis of the person, coupling of the human with its immediate neighborhood (e.g. an another person, a lamp) and the site of interaction on the human surface or within the head. This range of possible variations is to be considered as an order of magnitude estimate only due to the limited number of simulated situations and the coarse modelling of the human body.

For all individual contributions the worst case range of possible values is given in the Table C.1. Since no information about the actual probability distribution is available, a uniform probability between the lower and upper bound and zero probability outside is assumed. The standard deviation sigma of such a uniform distribution is then calculated according to

$$\sigma = \sqrt{\frac{(b-a)^2}{12}},$$

where a and b are the upper and lower limits of the range. In Table C.1, such calculated standard deviations are shown for all individual contributions.

If several factors determine the uncertainty of a quantity of interest (as is e.g. the case for the measured field value, see Table C.1, pos. 1.6), the individual contributions are assumed to be statistically independent. The overall standard deviation is then given, applying standard error propagation methods, by the square root of the sum of variances of the individual contributions. In Table C.1, the standard deviations for the relevant combinations of the influence are shown (pos. 1.6; 3.3; 6.1; 6.2; 6.3). Where appropriate, also the range ±2 standard deviation is indicated (pos. 1.6; 6.1; 6.2; 6.3). This range approximately corresponds to a confidence interval of 95%, provided that several influence factors contribute to the overall uncertainty and that none of them grossly dominates. This range of ±2 standard deviations has some importance in evaluating compliance with exposure limit values: according to BUWAL 1992 the measured field strength plus the total measurement uncertainty, expressed as 2 standard deviations (Table C.1, pos. 1.6), must not exceed the exposure limit.

Remark 1 *All uncertainties in this table are given in decibels (dB). x decibels correspond to a factor of*

$$y = 10^{x/20}$$

with respect to field strength.

Example 5
$$\begin{array}{ll} x = +2.9dB \rightarrow y = 1.4 & x = -2.9dB \rightarrow y = 0.72 \\ x = +10dB \rightarrow y = 3.2 & x = -10dB \rightarrow y = 0.32 \\ x = +20dB \rightarrow y = 10 & x = -20dB \rightarrow y = 0.1 \end{array}$$

	E [dB]		ΔE[dB]		H [DB]		ΔH [dB]	
	range				range			
	min.	max.	sd	2 sd	min.	max.	sd	2 sd
1. Measurement uncertainty								
1.1 Calibration uncertainty	-1	1	0.6		-1	1	0.6	
1.2 Linearity deviation	-0.25	0.25	0.15		-0.25	0.25	0.15	
1.3 Flatness of frequency response	-1	1	0.6		-1	1	0.6	
1.4 Anisotropy in uniform fields	-1	1	0.6		-1	1	0.6	
1.5 Additional anisotropy in local field gradients	-1.7	1.7	1		-1.7	1.7	1	
1.6 Total measurement uncertainty			1.45	2.90			1.45	2.90
2. Uncertainty due to unknown polarization of em. wave								
2.1 difference between equivalent and maximum field strength	-3	0	0.85		-3	0	0.85	
3. Temporal variations								
3.1 Varying propagation conditions for electromagnetic waves	-2.5	2.5	1.45		-2.5	2.5	1.45	
3.2 Varying operating conditions of the transmitter	-0.5	0	0.15		-0.5	0	0.15	
3.3 Total temporal variations			1.45				1.45	
4. Spatial variations								
4.1 Non-uniformity of fields in bedrooms	-6	6	3.45		-4	4	2.3	
4.2 Total spatial variations			3.45				2.3	
5. Dosimetric uncertainty (representativeness of measured field parameters for hypothetical dosimetric quantities)								
5.1 Variation of the local surface field strength along human body	-26	12	10.95		-1	5	1.75	
5.2 Variation of the local surface field strength along the head	0	12	3.45		-1	1	0.6	
5.3 Attenuation of the EMF within the head	-44	-28	4.6		-1	0	0.3	
6. Total exposure uncertainty (contributions 1 to 5) if point of interaction is								
6.1 localized at an unknown site on the body surface			11.65	23.30			3.6	7.20
6.2 localized at an unknown site on the head surface			5.35	10.70			3.2	6.40
6.3 localized at an unknown site inside the head			6.15	12.30			3.2	6.40

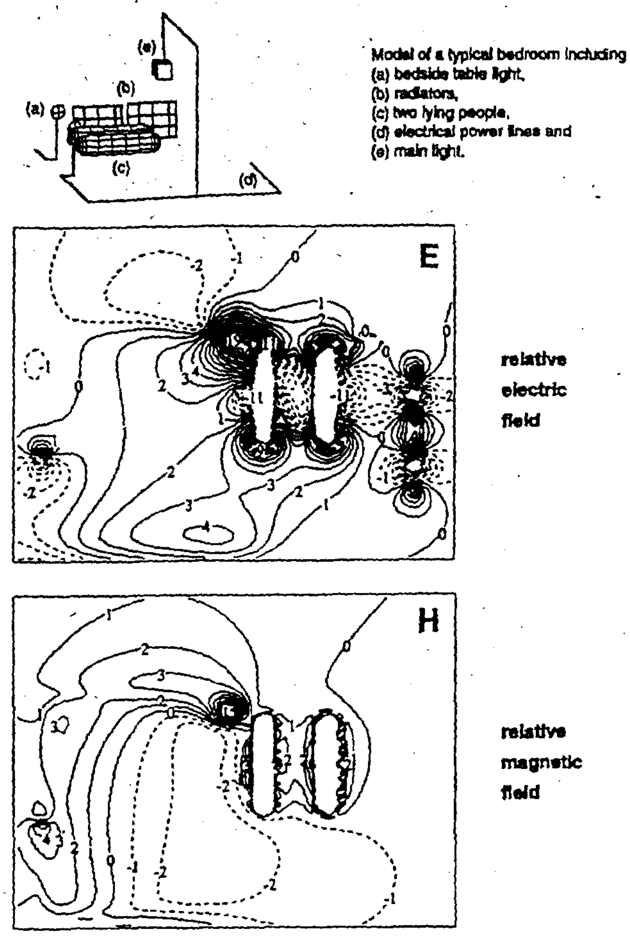
Table C.1: *Uncertainty of exposure assessment in Study II (sd standard deviation)*

C.1 Computer simulations

In Figure C.1 the spatial variations of the electromagnetic fields in a bedroom and the surface field strengths along human bodies are displayed. A simple bedroom is sketched on top of this figure which shows only those objects which may give rise to non-uniform fields. Such objects are either metallic or lossy dielectric objects including humans. The contour plot in the middle and at the bottom of Figure C.1 show the local distribution of the electric (E) and magnetic (H) field magnitudes due to an incident electromagnetic wave with 1 V/m (0dB V/m) amplitude. The calculations were performed by means of the method of moments. The full and dashed contour lines identify local areas with excessive($\geq$ 0 dB V/m) and decreased field strengths ($<$ 0 dB V/m) respectively. High field strengths have to be expected especially in the region of the bedside table lights and at the heads of the persons, high field gradients occur whenever one gets close to the surface of metallic objects or humans. The local field variations of the magnetic field strengths are considerably smaller than in the case of electric fields.

Figure C.2 shows the attenuation of electric and magnetic fields within a human body (finite element calculation). A two-dimensional model of a man was assumed with 'uniform' electrical parameters (relative dielectric constant ε_r and electrical conductivity σ) for the head and the rest of the body. The influence due to differences of biological tissue, bones, lung, heart etc. was not taken into account. Figure C.2 shows the local field variations inside the body due to an incident E-field of 0 dB V/m (left panel) and H-field of 0 dB A/m (right panel). Excessive field strengths along the surface of the body are not shown in this overview. Big differences between the attenuation of the electric and magnetic field strengths can be seen: more than 40 dB V/m for the E-field, and less than 5 dB A/m for the H-field.

Computer Simulation of Field Distribution Inside a Typical Bedroom



Contour plot of relative electric (E) and magnetic (H) field variation (in dB) at 15 MHz (horizontal plane, 1 m above floor).

source: EMC Baden Ltd. c/o ABB Research Center, 5405 Dättwil

Figure C.1: *Spatial variation of electromagnetic fields in a bedroom and surface field strengths along human bodies*